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ASSESSING THE IMPACT OF DROUGHT STRESS AT THE FLOWERING STAGE ON NUTRITIONAL CONTENT OF FINGER MILLET *(ELEUSINE CORACANA)*

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ABSTRACT

Finger millet (*Eleusine coracana* (L.) Gaertn.) is an essential minor millet crop known as ragi or nagli. Finger millet (*eleusine coracana*) is a vital crop for food security, particularly in water-scarce regions of India and Africa. Finger millet is a good source of micronutrients and dietary fibers. The calcium content of finger millet is 5 to 30 times higher than the other cereals. Drought stress significantly affects crop yield and quality, but its impact on finger millet's nutritional content remains poorly understood. This study investigates the effects of drought stress on the nutritional composition of finger millet, focusing on mineral, protein, and fiber content. A field experiment was conducted to study the effect of drought stress on nineteen-finger millet genotypes on nutritional composition. The nineteen-finger millet genotypes were evaluated under drought stress and non-stress conditions in factorial RBD with three replications. There were three plots: finger millet genotypes with well water (WW) (T_1) and water stress at the flowering stage (WS). The experimental result indicated significant reductions in Calcium (7.62%), Iron (6.06 %), and Zinc content (6.57 %) under drought stress at flowering stage stress. Genotype WN-566 showed the highest reduction in Calcium (6.49), zinc (6.99), and iron (8.49 %) content while, Genotype GN–9 showed the lowest reduction in Calcium (3.40 %), zinc (3.62 %), and iron (3.65 %) content in drought stress. There are several reasons for the reduction for reduction of minerals under water stress conditions that might be difficult for plant roots to absorb crucial elements like Iron and Zinc. As a result, the plant generally takes up ions from the soil along with water so the uptake of essential nutrients like zinc through the plant's roots results in a reduction in Ca, Zn, and Fe content. These findings have implications for crop breeding strategies for the future nutritional security under climate change areas.

***Key words*:** Climate change, Drought stress, Finger millet, Nutritional content, Protein Zn and Fe content

Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn.) is a subspecies of *coracana* belonging to the family *Poaceae*. Finger millet is an essential minor millet crop known as ragi, nagli, or african millet. It ranks third in importance among millets worldwide after sorghum and pearl millet.According to McDonough *et al.,* (2000) 97% of millets are grown and eaten in hot, dry regions of developing Asia and Africa, where they constitute the main source of nutrition for underprivileged farmers. Despite being the sixth most extensively grown grain worldwide, behind rice, wheat, maize, barley, and sorghum (Dwivedi *et al*., 2012) millets are usually viewed as a poor man's crop.

As of right moment, finger millet holds the greatest economic significance. However, the tribal farmers who grow other types of small millet, like proso millet, foxtail millet, kodo millet, barnyard millet, and little millet, also value them. Finger millet is a good source of dietary fiber and vitamins when eaten raw or cooked. Among the higher minerals in finger millet grains are Ca, Mg, and K. Compared to other grains, finger millet contains five to thirty times more calcium. Moreover, it contains 7.3% of protein on average and 44.7% of essential amino acids

Table 1: Effects of drought stress on calcium content of finger millet genotypes.

Calcium percentage (mg/100g)	**Waghai location**			**Bardoli location**			**Pooled**		
Genotypes/Stress treatment									
G1 (PR-202)	480.50	462.33	471.42	440.33	413.33	426.83	460.42	437.83	449.12
G2 (GN-8)	496.33	474.83	485.58	459.00	435.33	447.17	477.67	455.08	466.37
G3 (GPU-45)	396.00	378.00	387.00	396.33	379.67	388.00	396.17	378.84	387.50
G4 (GN-9)	489.83	473.17	481.50	496.00	472.67	484.34	492.92	472.92	482.92
G5 (GPU-67)	400.67	378.17	389.42	401.67	376.00	388.84	401.17	377.09	389.13
G6 (GNN-7)	396.50	377.00	386.75	397.00	378.00	387.50	396.75	377.50	387.13
G7 (WN-581)	392.83	370.33	381.58	393.67	368.67	381.17	393.25	369.50	381.38
G8 (GN-10)	452.83	430.17	441.50	452.67	427.67	440.17	452.75	428.92	440.84
G9 (WN-569)	393.67	371.83	382.75	394.00	370.67	382.34	393.84	371.25	382.54
G10 (WN-548)	362.50	344.00	353.25	363.00	345.67	354.34	362.75	344.84	353.79
G11 (VL-352)	396.33	376.17	386.25	397.33	377.00	387.17	396.83	376.59	386.71
G12 (WN-591)	393.33	370.33	381.83	394.00	367.67	380.84	393.67	369.00	381.33
G13 (WN-550)	395.83	374.17	385.00	396.33	373.00	384.67	396.08	373.59	384.83
G14 (WN-572)	329.83	309.50	319.67	330.00	309.00	319.50	329.92	309.25	319.58
G15 (WN-566)	336.67	314.83	325.75	337.33	313.33	325.33	337.00	314.08	325.54
G16 (WN-577)	374.17	356.17	365.17	373.67	357.33	365.50	373.92	356.75	365.34
G17 (WN-630)	390.83	368.00	379.42	391.67	365.67	378.67	391.25	366.84	379.04
G18 (WN-593)	399.33	380.17	389.75	400.67	382.00	391.34	400.00	381.09	390.54
G19 (GNN-6)	434.50	417.17	425.84	434.00	419.33	426.67	434.25	418.25	426.25
Mean	**405.92**	**385.60**	**395.76**	**402.56**	**380.63**	**391.60**	**404.24**	**383.11**	**393.68**

	Waghai location			**Bardoli location**			**Pooled**						
	T	**G**	**T × G**	**T**	**G**	**T × G**	**T**	**G**	**T × G**	**L**	**L × T**	**L × G**	**L × G × T**
S. Em. ±	1.23	3.11	5.38	1.25	3.15	5.45	0.88	2.21	3.83	0.72	1.24	3.13	5.42
CD @ 5%	3.46	8.71	NS	3.51	8.83	NS	2.45	6.17	NS	NS	NS	NS	NS
CV%	6.28			7.47			6.88						

Note: T_1: Control (No stress), T_2: (Irrigation withholding during 40-60 DAS

overall (Nirgude *et al.*, 2014).

An energy-packed meal is recommended for children, diabetics, and obese individuals. (Satish and colleagues, 2016; Ignacimuthu and Ceasar, 2012). It also has high levels of amino acids including methionine, lysine, and tryptophan as well as polyphenols (Chandrasekara 2011). Grain protein is rich in essential amino acids and antioxidants. Between 2016 and 2017, India's agricultural output amounted to 1.1 million tons on 1.1 million hectares, with an average productivity of 1747 kg/hectare (Anon., 2022). India's leading finger millet-growing state is Karnataka, followed closely by Uttarakhand, Maharashtra, Tamil Nadu, Andhra Pradesh, Gujarat, Orissa, Jharkhand, and Bihar. Given the growing demand for finger millet as a food crop and the declining amount of land dedicated to it due to competition from rival crops like maize and soybean, it is imperative to genetically increase the crop's productivity.

Events linked to global climate change, such as oxidative stress, salinity, drought, and extreme. In arid and semiarid regions, where drought is the major abiotic stress that seriously affects crop productivity, changes in precipitation patterns, increased intensity, frequency, and duration of dry periods, and growing water scarcity for irrigation all have an impact on agricultural productivity globally (Choudhary and Padaria, 2015).

Finger millets are more susceptible to drought stress since they are grown in semiarid and arid regions that receive rain very little. Finger millet was grown in the monsoon season when 25 to 30-day drought stress usually occurs at one or more of the latter stages of crop growth (mainly during the stages of grain filling and flowering). A drought during the 25-day stress period from earhead emergence during the grand growth phase reduced the grain yield by up to 18% (Nanja Reddy *et al.*, 2020). The most critical crop growth stage for drought stress response in finger millet is the earhead emergence stage (Anon., 2011). In the semiarid tropics, terminal drought occurs regularly due to limited soil water shortage for the cropping period length that hampered the reproductive growth of finger millet (Krishnasastry *et al.*, 1982). Even a short period of drought during critical growth stages of finger

Table 2: Effects of drought stress on Iron content of finger millet genotypes.

Iron content (ppm)	Waghai location			Bardoli location			Pooled		
Genotypes/Stress treatment									
G1 (PR-202)	3.93	3.8	3.87	3.95	4.06	4.01	3.87	4.01	3.94
G2 (GN-8)	4.49	4.3	4.40	4.50	4.31	4.41	4.40	4.41	4.40
G3 (GPU-45)	3.38	3.2	3.29	3.40	3.50	3.45	3.29	3.45	3.37
G4 (GN-9)	4.38	4.22	4.30	4.39	4.56	4.48	4.30	4.48	4.39
G5 (GPU-67)	3.18	3.24	3.21	3.20	3.27	3.24	3.21	3.24	3.22
G6 (GNN-7)	3.89	3.95	3.92	3.91	3.94	3.93	3.92	3.93	3.92
G7 (WN-581)	3.27	3.54	3.41	3.29	3.53	3.41	3.41	3.41	3.41
G8 (GN-10)	4.28	3.97	4.13	4.26	3.99	4.13	4.13	4.13	4.13
G9 (WN-569)	3.61	3.77	3.69	3.60	3.76	3.68	3.69	3.68	3.69
G10 (WN-548)	3.24	3.92	3.58	3.22	3.93	3.58	3.58	3.58	3.58
G11 (VL-352)	3.20	3.24	3.22	3.21	3.26	3.24	3.22	3.24	3.23
G12 (WN-591)	3.38	3.85	3.62	3.39	3.84	3.62	3.62	3.62	3.62
G13 (WN-550)	3.42	3.25	3.34	3.43	3.27	3.35	3.34	3.35	3.34
G14 (WN-572)	2.72	3.01	2.87	2.69	3.02	2.86	2.87	2.86	2.86
G15 (WN-566)	3.65	3.96	3.81	3.67	3.95	3.81	3.81	3.81	3.81
G16 (WN-577)	3.87	4.02	3.95	3.85	4.03	3.94	3.95	3.94	3.94
G17 (WN-630)	3.35	3.61	3.48	3.33	3.59	3.46	3.48	3.46	3.47
G18 (WN-593)	3.39	3.15	3.27	3.38	3.13	3.26	3.27	3.26	3.26
G19 (GNN-6)	4.35	4.11	4.23	4.35	4.09	4.22	4.23	4.22	4.23
Mean	**3.63**	**3.41**	**3.52**	**3.63**	**3.74**	**3.69**	**3.52**	**3.69**	**3.60**

	Waghai location			Bardoli location			Pooled						
	T	**G**	**T × G**	**T**	**G**	**T × G**	**T**	**G**	**T × G**	**L**	**L × T**	**L × G**	**L × G × T**
S. Em. ±	0.053	0.133	0.231	0.008	0.019	0.033	0.027	0.067	0.117	0.022	0.038	0.095	0.165
CD @ 5%	0.149	0.374	NS	0.021	0.053	NS	0.075	0.188	NS	NS	NS	NS	NS
CV%	3.39			4.41			3.90						

Note: T_1: Control (No stress), T_2: (Irrigation withholding during 40-60 DAS

millet markedly reduces the grain yield.). The most critical crop growth stage for drought stress response in finger millet is the earhead emergence stage (Anon., 2011). In the semiarid tropics, terminal drought occurs regularly due to limited soil water shortage for the cropping period length that hampered the reproductive growth of finger millet (Krishnasastry *et al*., 1982). Even a short period of drought during critical growth stages of finger millet markedly reduces the grain yield. Further, less attention has been paid to studying the impacts of drought stress on nutritional content in grain of finger millet so thus research focuses on this aspect.

Material and Methods

The experimental site, design and Treatments

In the current work, finger millet seeds were obtained from the hill millet research center, Navsari Agricultural University, Navsari, and a field trial was conducted at two locations *i.e.*, 1) Hill Millet Research Station Waghai, Gujarat 2) Wheat research station, Bardoli, Gujarat, India during summer 2022. The experiment was conducted in a factorial randomized block design (FRBD) with three replications, which included 19 genotypes viz., PR-202, GN-8, GPU-45, GN-9, GPU-67, GNN-7, WN-581, GN-10, WN-569, WN-548, VL-352, WN-591, WN-550, WN-572, WN-566, WN- 577, - 630, WN-593 and GNN-6 with three replications. The experiment was comprised of two treatments T_1: Control (Well-watered WW), and T_2: water stress at the flowering stage (WS). The crop was fertilized with 40 kg N_2 and 20 kg P_2O_5 per hectare. The nitrogen was applied in two splits, one at the time of sowing and the other 30 days after sowing. Entire Phosphorus was applied as a basal dose. Weeding was made to keep the experimental field free throughout crop season by following two hand weeding was done. Irrigation provided as per recommendation in the control treatment irrigation was applied every 10 DAS and treatment plot irrigation was applied as per the treatments. The experimental plot was kept free from any serious pests and diseases during the entire season.

Methodology

The seed calcium content (mg/100g) in the sample was estimated by the versenate titration method described by (Jackson, 1967), While the determination of Fe and

Table 3: Effects of drought stress on zinc content of finger millet genotypes.

Zinc content (ppm) / Genotypes/Stress treatment	Waghai location			Bardoli location			Pooled		
G1 (PR-202)	2.78	2.63	2.71	2.79	2.64	2.72	2.71	2.72	2.71
G2 (GN-8)	3.12	3.05	3.09	3.13	3.00	3.07	3.09	3.07	3.08
G3 (GPU-45)	2.77	2.61	2.69	2.75	2.80	2.78	2.69	2.78	2.73
G4 (GN-9)	3.04	2.93	2.99	3.07	2.90	2.99	2.99	2.99	2.99
G5 (GPU-67)	2.77	2.59	2.68	2.76	2.65	2.71	2.68	2.71	2.69
G6 (GNN-7)	3.06	2.87	2.97	3.10	2.83	2.97	2.97	2.97	2.97
G7 (WN-581)	2.97	2.74	2.86	2.99	2.66	2.83	2.86	2.83	2.84
G8 (GN-10)	2.95	2.80	2.88	2.93	2.77	2.85	2.88	2.85	2.86
G9 (WN-569)	2.87	2.75	2.81	2.87	2.76	2.82	2.81	2.82	2.81
G10 (WN-548)	2.90	2.75	2.83	2.88	2.69	2.79	2.83	2.79	2.81
G11 (VL-352)	2.93	2.75	2.84	2.90	2.63	2.77	2.84	2.77	2.80
G12 (WN-591)	2.90	2.76	2.83	2.90	2.75	2.83	2.83	2.83	2.83
G13 (WN-550)	3.07	2.97	3.02	3.08	2.99	3.04	3.02	3.04	3.03
G14 (WN-572)	2.65	2.56	2.61	2.66	2.57	2.62	2.61	2.62	2.61
G15 (WN-566)	2.86	2.66	2.76	2.97	2.84	2.91	2.76	2.91	2.83
G16 (WN-577)	2.81	2.58	2.70	2.82	2.60	2.71	2.70	2.71	2.70
G17 (WN-630)	3.00	2.82	2.91	3.01	2.85	2.93	2.91	2.93	2.92
G18 (WN-593)	2.96	2.86	2.91	2.85	2.54	2.70	2.91	2.70	2.80
G19 (GNN-6)	2.93	2.79	2.86	2.93	2.80	2.87	2.86	2.87	2.86
Mean	**2.91**	**2.76**	**2.84**	**2.92**	**2.75**	**2.83**	**2.84**	**2.83**	**2.84**

	Waghai location			Bardoli location			Pooled						
	T	G	T × G	T	G	T × G	T	G	T × G	L	L × T	L × G	L × G × T
S. Em. ±	0.014	0.035	0.061	0.005	0.014	0.023	0.007	0.019	0.033	0.006	0.011	0.027	0.046
CD @ 5%	0.039	0.098	NS	0.015	0.038	NS	0.021	0.053	0.091	NS	NS	NS	NS
CV%	4.15			3.14			3.81						

Note: T_1: Control (No stress), T_2: (Irrigation withholding during 40-60 DAS

Zn using the Atomic Absorption Spectrophotometric (AAS) method. Fe and Zn were estimated by the modified method described by Jackson (1967).

Statistical analysis

Data collected during this study were subjected to an ANOVA table. Statistical software OPSTAT was used for the analysis, while the critical differences were at a 5% level of probability.

Results and Discussion

Calcium content

The calcium content of finger millet as influenced by water stress is presented in Table 1. The calcium content of the nineteen-finger millet genotype is significantly influenced by drought stress at *P=0.05*. The result in Table 1 revealed that the varietal effects were significantly different for the calcium content in pooled findings. The results of a pooled analysis of both locations revealed that the maximum calcium content was recorded with genotype GN-9 (G_4) (456.00) followed by GN-8 (G_2) (449.78). The lowest mean calcium content was recorded in genotype WN-572 (G_{14}) (19.69), followed by WN-569 (G_9) (295.22). In Pooled analysis maximum calcium content was recorded under treatment T_1 (Control) (405.92). The lowest calcium content was recorded under treatment T_3 (Irrigation withholding during 60-80 DAS) (309.51). Treatment and genotype interaction (T×G) was found too non-significant.

There are several reasons for the reduction of Ca under water stress conditions that might difficult for plant roots to absorb crucial elements like calcium. As a result, the plant generally takes up less calcium ions from the soil. Another reason behind that within plants, calcium ions can be transported from older tissues to younger, actively growing tissues due to their mobility. However, when a plant is under water stress, the flow of nutrients through its vascular system may be restricted. Calcium content in particular areas may decrease because of poor calcium transfer from older to younger leaves or growth regions. Due to the decreased availability of water during water stress, other ions like potassium (K) and sodium (Na) concentrations in the soil may rise. These ions can interfere with calcium uptake by plant roots.

Iron and Zinc Content (ppm)

The iron and zinc content of finger millet as influenced by water stress is presented in Table 2 & 3. The iron and zinc content of the nineteen-finger millet genotype is significantly influenced by drought stress at $P=0.05$. The results in Table 2 & 3 revealed that the varietal effects were significantly different for the iron and zinc content in pooled findings.

The results of a pooled analysis of both locations revealed that the maximum iron content was recorded with genotype GN-9 (G_4) (3.84) at par with GN-8 (G_2) (3.76). The lowest means iron content was recorded in genotype WN-572 (G_{14}) (2.12). In Pooled, analysis maximum iron content was recorded under treatment T_1 (Control) (3.73). The lowest iron content was recorded under treatment T_3 (Irrigation withholding during 60-80 DAS) (1.58). Treatment and genotype interaction (T×G) was found too non-significant.

The results of a pooled analysis of both locations revealed that the maximum zinc content was recorded with genotype GN-8 (G_2) (2.91) at par with WN-550 (G_{13}) (2.88). The lowest means zinc content was recorded in genotype WN-572 (G_{14}) (2.42). In Pooled, analysis maximum zinc content was recorded under treatment T_1 (Control) (2.89). The lowest zinc content was recorded under treatment T_3 (Irrigation withholding during 60-80 DAS) (2.36). Treatment and genotype interaction (T×G) was found too non-significant.

There are several reasons for the reduction for reduction of Iron (Fe) and Zinc (Zn) under water stress conditions that might make it difficult for plant roots to absorb crucial elements like Iron. As a result, the plant generally takes up less (Fe) and Zinc (Zn) ions from the soil. The pH and redox potential of the rhizosphere can vary during water stress. The soil's ability to hold iron may be impacted by these changes. In particular, oxidizing circumstances or elevated soil pH might result in the creation of less soluble iron complexes, which lowers iron's bioavailability for plant absorption. Water stress can affect the availability of other nutrients in the soil. High concentrations of certain ions, such as manganese (Mn) and zinc (Zn), can interfere with iron uptake by the plant's roots. This competitive inhibition can lead to decreased iron uptake even if there is an adequate amount of iron in the soil.

Conclusion

The present investigation entitled "Assessing the impact of drought stress at the flowering stage on the nutritional content of finger millet *(eleusine coracana*). The field experiment was laid out in a factorial randomized block design with nineteen finger millet genotypes and three replications. The objective was to study the effect of drought stress on nutritional parameters. Water stress significantly affected Ca, Zn, and Fe content. Genotype WN-572 showed the lowest Ca (309.50), Zn (2.56), and Fe (3.01) content at the flowering stage. Genotype GN-9 showed the highest Ca (474.83), Zn (2.87), And Fe (4.54) content at the flowering stage. Furthermore, based on experiments it was concluded that genotypes GN-9 performed better under water stress conditions.

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